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UNTECHNICAL ADDRESSES ON TECHNICAL SUBJECTS

JAMES DOUGLAS

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Untechnical Addresses

ON

Technical Subjects

BY

JAMES DOUGLAS, LL.D.

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PREFACE

In reprinting the following addresses, omissions are made occasionally to avoid repetition. In other cases, in order to bring the information up to date or to amplify the subject, considerable additions are interpolated; but these, where they occur, are enclosed in brackets.

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CONTENTS

PAGE

THE CHARACTERISTICS AND CONDITIONS OF THE TECHNICAL PROGRESS OF THE NINETEENTH CENTURY.... 1

THE DEVELOPMENT OF AMERICAN MINING AND METALLURGY, AND THE EQUIPMENTS OF A TRAINING SCHOOL 39

WASTES IN MINING AND METALLURGY..... 60

The Characteristics and Conditions of the Technical Progress of the Nineteenth Century

(Presidential Address at the California meeting, September, 1899)

At this, the last meeting of our Institute for the last year of the century, it is appropriate that we should look back at the past.

To review the century's progress in the exact sciences and the resulting arts, that fall within the scope of our labors, is beyond my ability. But I wish to draw your attention to some phases of that progress which are almost as important, though they be within the zone of sociology—a science which touches at many points the domain of applied technology.

One of these is suggested by the library of technical literature which this century has produced —not the least important contribution to which is our own *Transactions*. The nineteenth century has witnessed the beneficial spread of democracy

in politics. Under the impulse, to no small degree, of the same spirit, there has grown up a brotherhood of fellow-workers and a sense of fellow-ownership in the secrets of nature. Though the Patent Office has assumed such proportions as to have become a source of national revenue, and a multitude of inventors, great and small, are seeking through its agency to secure some pecuniary profit from their devices, there is even greater eagerness among both interested and disinterested workers in the field of technology to publish their observations, and even their discoveries, and to give them to the world without remuneration. The motives influencing the great body of writers who, without any pay, use the technical journals and such media of communication as our *Transactions*, in order to give to the brethren of their craft the results of their often dearly-earned experiences, are various and complicated. But, in the majority of cases, the impulse originates in the desire for reciprocity, and in the hope that others will tell what they know, in return for what we ourselves communicate, and that therefore we shall learn at least as much as we can teach.

The spread of this healthy desire for liberal intercourse is assisted by the increase of means and opportunities for its gratification. Meetings such as this, for the personal interchange of thoughts and experiences, after a journey of 4000 miles, are possible only through the aid of railroads. The dissemination of our *Transactions* and of the great bulk of technical literature can be effected only through a government Post Office, working for the public good, and, in some of its departments, at unprofitable rates. These agencies have been the product of the nineteenth century, and only under their stimulus and through their machinery could such efforts be rendered practicable as technical men, the world over, are making for the furtherance of their common pursuits, interests and aims. Attribute the movement to what cause we may, I think it is fair to claim as one of the glories of the vanishing century the development of the spirit of open-mindedness and fraternal helpfulness, even in such self-seeking pursuits as those in which we are engaged. I use the word "development" advisedly; for I am far from admitting that progress in this direction has reached the consummation of beneficial

intercommunication which the twentieth century will witness, and which will aid mightily in the further advancement of science, as well as of art.

To-day, more than ever, technical experience is not only more freely discussed and disseminated than ever before, but the results of that experience, carried into actual practice, are more unreservedly than ever thrown open to technical inspection. The proof of this we, visiting members in attendance at this meeting, have experienced at every step of our journey. There are few great metallurgical works in this country, entrance to which is refused to a visitor who has any real right to ask for admission.* In Europe, even, where old conservative practices are more enduring than here, the barrier of exclusiveness is being rapidly broken down. As a rule, those establishments whose doors are most sedulously closed are those least worth studying, except as technical anachronisms.

Moreover, I think it may be accepted as a fact

* This observation does not apply in full force to chemical manufactories, where there are supposed to be more secret processes worked behind-doors than in any other branch of technology.

that those branches, especially of metallurgy, which have made most progress, are those in which least secrecy and reserve have been practiced. No art has made such marvellous strides as the manufacture of iron and steel. Speaking from my own experience, I may say that I have never been refused admission to any iron- or steel-works on either side of the Atlantic, not even the works of Mr. Frederick Krupp, at Essen. But though iron-masters abroad may freely throw open their doors, our own American iron-masters are even more liberal in communicating their plans and methods. Managers from England, smarting under American competition, who have come to this country to visit our furnaces and rolling-mills, with the avowed object of borrowing their plans, have expressed to me the greatest wonder and admiration at the frankness with which they are allowed to study the great works which have demoralized prices the world over.

Not only do the iron- and steel-workers of every land bid their rivals enter and view the titanic feats, which each vies with his neighbors in performing:—they seem to take delight in telling their very secrets. Certainly no special

literary organ of any art contains such frank discussion of processes and methods as the "Journal of the Iron and Steel Institute," which is not the Institute of Great Britain, as popularly supposed, but of the world. Such periodicals as the "Iron Age," and other organs of the iron-industry in its several phases, illustrate the liberality of the iron men in even giving their working-plans to their fellow-workers. It may be inferred, therefore, with justice, that the progress achieved in iron- and steel-making, and the delightful candor with which iron-masters discuss their trials and tribulations and explain the solution of their difficulties, are related, not accidentally, but intimately, as cause and effect.

I wish I could say the same, as unreservedly, for the branch of metallurgy in which I am more immediately interested—that of copper. Some of our largest works still close their doors against strangers. The only locality, however, where rigid secrecy is almost completely maintained is Swansea; and there, I imagine, we would find, if admitted, little to learn which was not described generations ago. Is it not possible that one reason why we are now robbing Swansea of so

much raw material, coming even from British colonies at the antipodes, is that she refuses to either give to, or take from, the world's supply of technical information? The managers of such progressive English works as those of the Cape Copper Co. and the Rio Tinto Co., where there are actual novelties to be studied, are willing to throw them open to students.

As an example of what might be gained by interchange of experience, I may be allowed to draw an illustration from a branch of copper-metallurgy. In this country and Europe there is a refining process, the operation of which some, though not all, of those who practice it, guard from inquisitive eyes with timorous care. I refer to the electrolytic process. But I need not remind those of you who attended the recent New York meeting, still less those who have just visited the electrolytic establishments at Great Falls and Anaconda, that this dread of inspection does not possess the managers of all our great copper-works. It is understood that this is a branch of metallurgy dependent for success on the nice adjustment of a number of chemical and physical factors, and that the sixteen or eighteen works

which practice it on a large scale in this country and Europe have acquired, only after much trouble and serious expense, the experience which enables them to turn out copper of invariable quality with almost absolute certainty. After spending time, labor and money in overcoming the difficulties which mysteriously and unexpectedly turn up, the owner of a copper refinery deems it unbusinesslike to divulge the solution of these problems, and thus place his rival's works on equal footing with his own. But, in reality, his rivals have all been battling with exactly the same foes, and most of them have been victorious. The result, therefore, of a mistaken reticence is, that each of the works has had to expend, in surmounting exactly the same obstacles, six or seven times more money and energy than if all had been willing to exchange experiences. There is very little to choose between one brand of electrolytic copper and another. All are good; and all have been brought to the present high standard by separate labor and separate series of experiments, in separate establishments; whereas, had there been co-operation on points of purely technical manipulation,

the same results would have been attained with an immeasurable saving of time, mental wear and tear, and financial expenditure. It is difficult for a skilful manufacturer to appreciate and admit this. But that a truer appreciation of the value of the higher principle of co-operation has taken possession of our copper refiners is evinced by the publication of such a paper as that of Mr. Keller, the Chemist of the Baltimore Copper Co., in the last volume of the *Mineral Industry*.

I have used the above instance, drawn from copper-metallurgy, as an illustration of the wasteful effects of secrecy, and because it stands out in such a glaring contrast to the nobler practice of mutual helpfulness, which has been one of the most potent forces in raising all manufacturing, but especially that of iron and steel, to the exalted position it has attained during the latter half of the century with which we are regretfully parting.

As time goes on, and a generous dissemination of personal knowledge, even if it be not strictly practical, becomes the rule and not the exception, it will be discovered that, after all, success in manufacturing will depend as much on the

personal energy and skill with which the knowledge is applied as on the possession of the knowledge itself.

Whether we will or not, secrecy, as a business method, is becoming almost obsolete under the prying scrutiny of the press and the telegraph. The old rules of business, dependent on reserve and on news secured in advance of one's neighbor, have given place to new methods. The chronicle of the world's doings is at the disposal of any one for a few cents, every morning of the year. But a man of business genius draws from it conclusions very different from those of his less imaginative or less enterprising rival. Both men may possess, as stock in trade, the same facts, but the abler man makes successful use of them. His correct and far-sighted deductions lead him to adopt a policy and pursue a course of action as different from those of his sluggish competitor as if he had himself possessed special sources of information.

And so it is in the practice of our peculiar arts. The personal element determines the success of one man and the failure of another, though both start out with the same store of facts. Neverthe-

less, the more facts he has, the more rapid will be the rise of the man of genius, while the pace of the other will certainly not be retarded. The man of genius, therefore, need not grudge the communications of his facts to his less progressive competitor, provided he learns, in exchange, what few facts his slower neighbor may have picked up by the way.

While all must admit that the world's rapid advance in material well-being has been due to the dissemination of knowledge, and that this can be effected only by the breaking down of the barriers of secrecy, some of our brethren have yet to be persuaded that there are few, if any, limitations to be set to this universal law. Unfortunately, many barricades, raised by mistaken selfishness, are still to be stormed and demolished. But the coming century will in this respect carry forward the work of the receding age, whether we shall see its accomplishment or not. At any rate, we may congratulate ourselves that societies such as ours have aided to further so good a cause, not only as media of communication, but also as sources of influence—for the most confirmed secret-keeper cannot benefit by the candid

revelations of his rival without some compunction; and, sooner or later, reform follows repentance. It is, therefore, not presumptuous to hope that, as the scientific temper more and more permeates the habits of our technical workers, the old fashion of relying on secrets for success will be replaced by the truer method of generous giving and thankful receptivity.

At present the world's acquisitions in pure, and, to a great extent, in applied science, are thrown into a common stock, from which the technical worker draws what he wants without stint. He, in his turn, is coming to acknowledge and recognize the truth that it will be to his advantage to enlarge the sphere of unreserved intercommunication until there shall be no trade-secrets; for then, while society will be the gainer, he himself will be able to draw from a larger capital of facts than now stands to his credit. Moreover, it may accepted almost as a law of nature that the preson who has not cultivated the habit of mental giving acquires a spirit of narrow exclusiveness which cramps the faculty of open-minded receptivity—for receiving and giving are reciprocal intellectual motions.

Though the influence of individuals on the industry of the country is keenly felt, national progress, in its widest range, is not made through the impelling force of one man, be he ever so able. It results from the united efforts of many minds and many hands, acting under the contagion of a common inspiration. Looking at the development of a whole people, or of a single industry as a unit, we may therefore perceive that the old habits of secrecy in manufacturing enterprises frustrate the very object which the secret-keeper aims at; for while he is guarding behind double doors his depreciated treasure, the great army of progress is marching past him.

To a certain extent, community of ideas and methods is secured through such combinations of capital and manufacturing interests as have become the most prominent features of modern industrial development. All the peculiar processes and methods (if there be such) practiced by each of a dozen combined mills become the property of the unified concern, and can be applied in all its establishments. But should the result of industrial combinations be the reversal of the tendency towards freer discussions, and

should the managements of these tremendous aggregations of power prohibit on the part of their employees all discussion of technical subjects, a strong prejudice against their existence would be created in the public mind, which naturally distrusts all secretiveness. The public will not unreasonably conclude that if one of the great economical benefits which accrue from such combinations is the "pooling" of individual secrets, much greater would be the general benefit if all reserve should disappear, and the technical facts learned by each industrial combination were communicated to all, as freely as Röntgen gave to the world his discovery of the "X" rays. Ours is stigmatized as a mercenary age. Nevertheless, there is a spirit of fraternal helpfulness abroad in the world. I believe that before long he will be honored as the most successful man who has communicated to his fellow-craftsmen the greatest number of useful facts and the largest stock of valuable personal experience; and I believe, also, that any combination of selfish men or interests which may try to withstand this rising tide of free thought and free speech will be swept away.

As I have already remarked, this modern spirit

of voluntary interchange of thought and experience has been stimulated by the means of transportation and communication which alone have made its effective operation possible. Railroads, steamboats and the telegraph have been the apostles and missionaries of free thought and free speech. But they have served another purpose. They have virtually determined the current of population and the drift of mining and metallurgical industry.

It is difficult to realize the diminutive proportion of human settlement on this continent during the first three decades of this century. In the year 1800 the population of the United States was 5,305,937. There were only 903 post-offices and 21,000 miles of post-roads—and very bad roads at that. The Post Office revenue amounted to only $231,000; and only four cities could boast of a population exceeding 10,000 inhabitants.

In 1830 the population had increased, chiefly by natural increment, to 12,860,020. But the manufacture of metals was still a local industry; and so it continued for nearly two more decades—while the railroad system of the country was expanding, so as to link section with section and

fuel with ore. The year 1830 was economically the critical period of our history, for in it the railroad first appears as a factor in our industrial life. Twenty-three miles of track had been laid. By 1840 locomotives were running over 4535 miles of road, and in that year the first attempt was made to incorporate industrial statistics by quantity, instead of value, in our census-returns.

If we compare two items of the statistics of 1840 with the same in 1899 we shall appreciate how potent the railroad has been as a controlling power in mining and smelting, and what a revolution it has wrought in the industrial life of the nation.

As we have said, in 1840 there were 4535 miles of railroad in operation. In 1840 there were scattered over the inhabited sections of the country 804 small blast-furnaces, making 256,100 tons of pig iron. In 1899 our railroad system included 250,142 miles of track, and there were made in 200 blast-furnaces 13,620,703 tons of pig iron. If we multiply by 53 the number of miles of railroad in operation in 1840 and the number of tons of pig iron made in that same year by the same multiplier, we get approximately

the mileage of track now in existence and the tonnage of pig iron turned out by our blast-furnaces, viz., 249,425 miles of track, instead of 250,142, and 14,085,500 tons of pig iron instead of 13,620,703. The relation cannot be accidental,[1] for there is every reason why the magnificent iron industry of the country should keep pace with the extension of its railroad system. The lines of growth have not always been perfectly harmonious, but there has never been any wide divergence from parallelism.

[Though the production of pig iron since 1898 has increased more rapidly than the mileage of the steam railroads, if the mileage of the extra-urban electric and steam street roads, and the increase in second tracks, be added to that of the railroads, the ratio is closely maintained. Recently the miscalled street railroads,—as urban, suburban and interurban roads—have been extended in competition with the railroads from town to town, and in some cases are constructed on the standard of a railroad, with heavy steel and rolling stock for freight. The Union Traction Co. controls not less than 1201 miles of road, centering in Philadelphia; the United Power &

Transportation Co. controls some 220 miles; and the United Traction Co. of Reading 650 miles. In California, the system centering in Los Angeles has in operation or under construction 826 miles of track. In 1904, the mileage in operation or under construction of these street railroads in the United States, has reached a total of about 28,000 miles. The Census Bulletin Number 3 reports for 1902, 22,589 miles as in operation. In 1903 the number of miles of railroad track was 283,821. If to this be added 28,000 miles of street railway track, we have a total mileage of 311,821. The pig iron production for 1903 was 17,942,840. If, therefore, the pig iron production of 1840 be multiplied by 70, we have 17,927,000 tons, as against the actual production for that year of 17,942,840. And if the railroad mileage of 4835 in 1840 be multiplied by the same multiplier, we have 317,450 miles of track, as against the actual of 311,821 miles of track.]

Equally important in its bearing on the iron-trade has been the development of inland navigation. The difference between the first steamer, "Walk on the Water," that timidly ventured

out on Lake Erie, and the present large iron steamers, which, with their consorts, last year transported 14,000,000 tons of iron-ore from Lake Superior ports, is as great as between the "John Bull" of the Mohawk & Hudson R. R. and No. 999 of the N. Y. Central & Hudson River R. R. [The tonnage of the steamers on our Lakes, especially those devoted to the transportation of iron-ores, is growing as rapidly as the size of our railroad trains.

The "Augustus B. Wolvin" and the "Sahara," the two largest boats on the Lakes, were both launched in 1904. Their dimensions are:

	Length, Feet.	Beam, Feet.	Depth, Feet.	
"Wolvin".....	540	56	32	10,000 gross tons on draught of 18½ feet
"Sahara".....	474	52	29	8,000 to 9,000 gross tons

Of vessels plying the Great Lakes there are 67 having a tonnage capacity exceeding 4500 gross tons. Nineteen of these have a tonnage capacity exceeding 5000 gross tons.]

With increased size of, and improved machinery in, vehicles on land and water, the cost of

transportation has correspondingly decreased, until freight has been carried, on long-distance hauls, with profit to the railroad company, for four mills per ton-mile. [Railroad freights on certain commodities are as low as even two and a half to three mills per ton-mile for long hauls.] The data for comparison with former freights are scanty, but the statistics of the Fitchburg R. R. give us as the average freight rate in 1848 4.523 cents, and in 1897 0.870 cent per ton-mile.

When Lake Superior began to ship iron-ore, in 1857, the transportation-charges were about $3 per ton to Lake Erie ports. The "wild" and "daily" rate in 1897 was 55 cents; the contract-rate, 65 cents. From Escanaba it was only 45 cents, and from Duluth 57 cents. Freight has been transported across the Atlantic, a distance of 3000 miles, for a little over $1 per ton. This obliteration of distances by steam-power has altered completely the commercial and even the social conditions of the country. Before the railroad and steamboat produced the industrial unification of the continent, not only were food and clothes the product of local and domestic manu-

facture, but such a necessary article as iron was cast in small furnaces or reduced in small bloomeries, wherever iron-ore and charcoal were found, even in limited quantities, near a water-power. To transport either fuel or ore for any distance over bad country-roads to large establishments was less economical than to run the village furnace or forge. With the appearance of the railroad commenced the concentration of raw material and the shifting of the centers of the iron-industry to a few favored localities. The process has continued ever since, to the serious detriment and even destruction of some of the older mining and metallurgical districts, and the creation of prosperous communities in what was, a generation or two ago, an inaccessible wilderness. Ore and fuel need no longer occur in natural juxtaposition: ore from the Mesaba range in Minnesota, has been delivered at so low a figure at Pittsburgh, in Pennsylvania, that, when turned into iron and steel by the aid of mechanical appliances, steel rails have been made from it, and sold at $16 per ton. It is less than a generation since Bessemer rails, made by the same process, but out of costlier ores and by cruder appliances,

cost $120 per ton. In very truth, so obedient have the forces of nature become to the will of man that weight and distance, which were, in the days of hard labor and horse-carts, controlling considerations, are being well-nigh eliminated from the calculations of modern engineers.

Cheap transportation has not affected the iron industry alone. It has made it possible to utilize the copper- and lead-ores of the West, and to reduce the cost of their treatment, by taking advantage of neighboring natural facilities. For instance, the Anaconda Co. transports its ore for a few cents from Butte to water at Anaconda, 38 miles distant; and it is advantageous to carry Boston & Montana ore over 176 miles to water-power on the Missouri River. But the very romance of transportation was reached in the following instance: matte was bought at full price in Tennessee; transported by rail to Norfolk, Va.; then shipped to Tampico, in Mexico; carried half-way across that Republic; saturated with gold and silver; concentrated into black copper, and brought back by rail and water to New Jersey for electrolytic treatment! Everywhere the same wonderful interchange of products

and transfer of energy from one part of a land to another, or from one country to another, are being effected by the same agencies, thus making the whole world kin, and more or less interdependent as well as independent. With further improvement in motive-power by land and sea, the present cost of transportation, low as it is, will be steadily reduced, until the day will come when the natural resources of every land will be the common property of the whole world. Already the great German iron and steel plants of Stettin rely entirely on imported crude material. England, Germany, and France draw most of their supply of iron-ore from foreign lands. Even we ourselves do not depend altogether on home supply. And when we review the world's resources, we must be convinced that the quantity available within economical reach is so enormous as to preclude all risk of failure from the exhaustion of raw material or of the acquisition by any one country of a monopoly of manufacture. In the north of Sweden, within the Arctic circle, are iron ore deposits of phenomenal size.

Since 1899 these enormous deposits of iron-ore have been rendered accessible by a railroad ter-

minating at Narvik or Victoriahavn on the Atlantic, a port free from ice the year around. The railroad was opened on November 15, 1902, but the docks of Narvik are not yet completed. The Gellivara mines have been shipping over 1,000,000 tons of ore a year over a railroad which has been open for several years to Lulea on the Gulf of Bothnia, a port which is closed by ice during the winter. But the Gellivara is one of the smaller deposits. The Kürunavaara deposit has a continuous length of over two miles and an average width of about 300 feet, and its extension, the Luossavaara deposit, which has not yet been touched, is estimated to contain above the level of Lake Luossagaivi 218,000,000 tons of ore. That the ore contains on an average far too much phosphorus for treatment on an acid bottom is considered no disadvantage by the German works at Lulea, where some of the phosphorus is separated mechanically as apatite, as is now done on Lake Champlain, for treatment by the German steel works, who have no prejudice against the basic bottom. The Kürunavaara-Luossavaara deposit is only 105 miles by railroad from the port of Narvik. The Gellivara deposit

is 168 miles, and the Roulevara deposits, which are almost as extensive as the Kürunavaara-Luossavara deposits, lie only 70 miles west of Gellivara. There are therefore within an area not larger than that comprised within the Mesaba and Vermilion Ranges deposits of iron-ore remarkably high in iron, though high also in phosphorus, whose horizontal section is approximately 1,000,000 square meters, and containing above the surface not less than 500,000,000 tons of ore. Their accessibility to the markets of Northern Europe compares favorably with that of our own Lake Superior ores to our own iron centers. The average distance which the Kürunavaara-Luossavara ores must be carried to reach Narvik is very few miles greater than that over which the ores of the Mesaba and Vermilion Ranges are transported over the D. & I. R.R. or the D. M. & N. Ry. to the docks on Lake Superior. Once on board ship the Swedish ores travel 1170 miles to reach Middlesborough as against 834 miles which is the distance of Duluth from Cleveland, or 985 from the same point to Buffalo. If consigned to Pittsburgh furnaces, the Lake Superior ore has to be trans-shipped at an Erie port and

carried by rail 150 miles further. The climatic conditions for transportation and the geographical relation of the Swedish ores to the furnaces of Northern Europe are as favorable as that of the Lake Superior ores to our furnaces on the Lakes, and more favorable than their relation to Pittsburgh.*

According to the *Engineering and Mining Journal*, it is reported that four of the largest iron producers in Germany, including the Gutehoffenung, Deutscher Kaiser, Rheinische and Krupp companies, have entered into a contract with the Trafaktiebolaget Grängesberg Ocselösun, the owners, for the delivery of 14,000,000 tons of iron-ore. The shipments are to be made via Emden and Holland ports. The ore will be mined from the deposits of Grängesberg, Gellivara and Kürunavaara.

On the shores of Hudson Bay, of Baffin Bay, and of Newfoundland large deposits of iron-ore occur, which are not excluded by ice for a much

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* Lundbohm, *Iron-Ore Fields of the Province of Norrbolten, Stockholm*, 1898, and W. F. Wilkinson on "Iron-Ore Mining in Scandinavia" *Transactions* of the Institution of Mining and Metallurgy.

longer period of the year from the market of the world than are ours by like obstacles from our own markets; [and very extensive deposits of high grade ore exist almost on the Pacific coast of Mexico. This seems a locality far from the commercial centers of the world, but when the Panama Canal is opened, it will be within the circle of accessible commerce]. When our canals shall have been enlarged, or new ones shall have been built, Lake Superior ores may find their way to European furnaces almost as cheaply as to Pittsburgh. [While no Lake Superior ore has as yet been shipped in quantity to Europe, Lake Champlain mines have consigned large shipments to Scotland and Holland. The *Engineering and Mining Journal* is responsible for the statement that in June of 1904, 12,000 tons were sent, to be followed by 18,000 tons more to cover contracts of 30,000 tons. This ore is shipped by Witherbee, Sherman & Co., and is from the mines owned by that company, in the Lake Champlain district in New York. The ore is carried from Port Henry by Lake and Canal to New York harbor. The movement has been favored by low ocean rates, the charge from New York to Antwerp

being about five shillings, or $1.20 per ton.] California has drawn coal from New South Wales and sulphur from Japan. England depends largely on New Zealand for her fresh mutton; and our wheat, beef and pork feed the population of the world. Thus nature's commodities, now that we are learning how to control and use nature's forces, are becoming the common property of all mankind. If that be so, and if the world's resources are in the future to become more and more cosmopolitan, the race for industrial preeminence will not necessarily be to those who possess within their own national domain the crude materials for workmanship, but to those who by native wit and scientific learning and acute research can, out of the crude material, manufacture, most cheaply and of best quality, just what the world at large wants. And therefore, if certain groups of the world's inhabitants progress more rapidly than others, it will not be altogether or primarily because they possess an undue share of nature's material gifts, but because they evince more aptitude in availing themselves of the opportunities which nature offers them.

Our own industrial growth has excited the wonder of the world. While it is true that our progress would not have been so rapid and so far-reaching in its influence, had the nation not possessed within its own boundaries natural resources as extraordinary for their diversity as for their quantity, certain political and social forces have concurred in facilitating our growth. Only two generations have passed since the era of our rapid industrial advance began. Since then we have been able to tap the untouched resources of a whole, marvellousiy rich continent, with the whole world's past experience to draw from, while relieved from many of the social and industrial complications which impede free action in the Old World. Never in the history of mankind have so many favorable causes combined to assist the industrial development of a people. During the first half of the century, few sordid distractions withdrew the nation's energies from the greatest task a people can undertake—the creation and consolidation of a system of popular government. With the establishment of this on a firm basis, the discoveries of modern science and technology coincided. Thus a free nation was

enabled to turn to account its splendid resources with the aid of appliances and natural forces which were contemporaneously and for the first time being brought under the control of mankind. Yet, for all that, had there not been certain qualities in the national character, or, perhaps, to speak more accurately, in the spirit of our industrial classes, these bounties of nature would have remained hidden or neglected.

When we try to analyze the social influences which have been, apart from the natural advantages of this country, the impelling causes in bringing about its rapid rise in the industrial scale, certain differences which distinguish the conditions existing here from those of the older industrial centers of Europe are very conspicuous. Labor, generally superabundant abroad, has here been scarce, and therefore dear. To this cause is, in part, though not altogether, attributable our substitution of machinery for hand-labor in every department of life. To consider the ultimate effect of this substitution on our national life is beyond our province, but is is almost certain that this elimination of manual labor is exerting both an elevating and a depraving influ-

ence on our working classes. The handling of machinery requires, in some vocations, a keener intelligence than the manual use of tools. The engineer of a steam-hoist brings into play a set of faculties very different from those exercised by the men toiling at the handles of a windlass. The gunner of a modern man-of-war must be somewhat of a mathematician as well as a sailor. On the other hand, the effect of repeating, day in and day out, the same series of manual operations, in keeping up with the unvarying speed of a machine, tends to reduce the man to the level of the machine itself, and must have a most benumbing effect on the faculties. The all-round mechanic of former days is rapidly becoming extinct.

A factor in our progress which should not be overlooked is that our miners and metallurgists have the advantage of working new mines and starting and operating new smelting works, instead of being the successors of generations of eminent men, whose fame was in all the schools, and to question whose methods, and even their theories, were heresy. The conditions facing the trained miner and metallurgist even in the East,

but especially in the West, are so different to those for which rules and precepts were laid down by his teachers, that he had of necessity to depart from precedent, and shape out for himself new machinery and adopt for his practice new processes, while living up to the scientific principles which must underlie all successful work. It is easier, however, for him to do so than it is for the manager of Old World establishments to adapt himself to altered conditions, and more modern methods. Even if his reverence for the past be as profound, and his knowledge of its ways as deep, as those of his European confrères, it wounds him less to tear himself away from the old ways which have become almost sacred through long practice than it would be for the manager of works in Saxony or the Hartz, or Swansea, to desecrate the memory of his ancestors.

Again, while it is true that without the scientific assistance which highly trained metallurgists have contributed to our American miners and metallurgists who compose so large a proportion of our operating staff, our eminent position would not have been attained, unless the initiative had generally been taken by men who

brought native wit rather than training to bear on the solution of the many new problems that have presented themselves.

And this spirit of originality, not of revolt against the past, influences the business department of our important enterprises as keenly as it does the operating. It is seen in nothing more conspicuously than in the worthlessness attached to an old plant; the recognition of the fact that it is intrinsically valueless except for the work it is actually doing, and that as soon as it falls behind the plant of a competitor in efficiency it must be torn down and replaced by another, which will enable its owner to maintain his position. Of course, this expensive practice is economical only when applied to works where the saving on the unit of production is so large as to warrant it, and where, as invariably happens, the new plant introduces new mechanical appliances, which reduces the labor cost. Nevertheless, the willingness with which capital thus wipes out what stands at such a high figure on its books, the certainty with which it anticipates that business will grow and not decline, and the cheerfulness with which it faces depression and even dis-

aster, when buoyed up with this confidence, are traits which have distinguished American mining and metallurgical companies, in all departments, from their foreign competitors.

In many other respects our rivals in trade are handicapped, and it is fair that we should take credit only for what we really deserve. In this country, few local ties bind the employer and the employed. In the Old World the case is different. There certain branches of manufacture have been planted for generations in the same locality. The business has been conducted by the ancestors of the present owners, and the work has been done by the ancestors of the present operatives; and there has grown up a certain sense of joint interest, if not common ownership, in the works. This makes difficult the introduction of modern methods and of modern machinery, which, to say the least, necessarily involves a dislocation of old associations. In the famous Krupp works at Essen, for instance, the house, not bigger than a hut, in which the founder of the famous firm lived, is preserved as the nucleus of the existing wonderful mill, as sacredly as though it were the sanctuary of a

temple. In going through the plant, I observed that the Bessemer converters were idle. All the steel was being made in the open-hearth furnaces. I asked my guide what had become of the Bessemer workmen. He said they were being employed on buildings for a new colony. I, not unnaturally, observed that steel-workers must prove unhandy operatives at any other craft; but my guide replied that Mr. Krupp never discharged a faithful man if it were possible to find temporary employment for him in some other department. Such a sentimental motive seldom influences our great employers of labor; and our independent workmen would despise as unbusiness-like such a procedure.

[Shortly after my visit to Mr. Krupp's works I met an American manufacturer who told me that by introducing electricity as a motive power from a central station he had been able to discharge five hundred workmen. I asked him what had become of the five hundred. His reply was that there is plenty of vacant land in America as well as vacant employment for them. Their future gave him no concern, nor perhaps need it have done so.]

Looking at this phase of our industrial system from an economical point of view, the absence of such sympathy, and the latitude it allows to our manufacturer to do what self-interest suggests, materially aid in introducing economies which (at any rate, temporarily) give him an advantage over his European competitors. Abroad this bond is so strong between the owners of old works and the descendants of the ancestral workmen, that I know of one large establishment in Britain which is anxious to introduce modern appliances, involving a change in methods so radical as to require the discharge of a very large number of its old hands; but the odium and opposition incurred by doing this in the home of the old industry would be so intolerable that, rather than face them, despite the economical absurdity of the alternative recourse, the old works will probably be completely abandoned and new ones will be erected in a distant portion of the kingdom.

It is difficult for us to appreciate the gravity of such obstacles to change and progress; and yet, at the same time, one regrets that before the inexorable claims of modern mechanical

progress, the fine family feeling of co-partnership, in which such obstacles originate, should be crushed. And, looking beyond the present, we must perceive that on the solution of these difficult and obstinate problems the advance of some over others of the great industrial communities of the world in the twentieth century will depend.

We shall, however, commit a grievous mistake, if we imagine that the reaction of our example upon Europe will not be as sensitively felt as the influence of Europe has been felt by us in the past. England is more seriously handicapped than any of the progressive peoples in reorganizing her industrial household, by the fact that for half of the last century she was the paramount power in the industrial world, and that it is difficult for any country thus situated to reach the conclusion that some, even, of the machinery and methods of trade and manufacture, which gave her supremacy, may have become obsolete, and should be discarded. But she is rapidly recognizing the truth that conditions have changed, and that she must change with them. Germany, on the other hand, and to a lesser extent Belgium and France, started on the new development of

their mineral resources at a later date than ourselves, and are less weighted down than is England by old plants and old prejudices.

As all these vigorous competitors are in the field, and will be bidders against us in the markets of the world, which we are about to enter, and rivals even in our own markets, we will make a grave error if we count on victory mainly through the resources of the coal and the iron-ores, which we possess within our own land; for the conclusion and lesson I would rightly or wrongly draw from the preceding general survey is, that the industrial standard of a nation in the twentieth century is likely to be determined more by its capacity for progress than by its mere possession of crude natural resources. Not only the world's primary supplies, but also the world's technical experience, are becoming more and more the heritage of all; and consequently the lead will be taken by the nation whose technical managers possess skill, stimulated and not stunted by education, and so directed as, by elevating the intellectual condition of its operatives, to prevent them from sinking to the level of mere cogs in the wheel of a soulless industrial machine.

The Development of American Mining and Metallurgy, and the Equipments of a Training School

An Address Delivered before the School of Mines and Metallurgy, of the University of Missouri, May 30th, 1901.

GENTLEMEN:

I have been asked to address you to-day on the twin subjects of the Development of American Mining and Metallurgy and the Requirements of a Mining School, for which please understand the requirements of a student after he has left a Mining School. The subjects are so closely related that the elucidation of the one will serve as a text to the other. I will not bore you with a table of statistics, which are forgotten by the hearer as rapidly as uttered by the speaker. They certainly flatter our national vanity, but are not, in so far as they consist merely of unrelated columns of figures, especially useful. Some day or other the statistical branch of political

economy may be reduced to the order of a science. When this is done even mineral statistics may assist us in forecasting the future, which is one of the provinces of science, and thus in a certain sense, give stability to our industrial system —if system it may be called. This will come about when we trace the industrial relations of metals to one another and to the vicissitudes of economic life. Take for instance the fact that the production of pig iron in this country and the increase in mileage of our railroads have almost exactly kept pace during the last sixty years; or the further fact that the production and consumption of iron and copper, taking the world as a whole, during the past half century has grown in equal proportions. If we could trace a number of such relations, we would have partial data on which to predict the activity of a given branch of metallurgy when the country was enjoying prosperity, or the depression which must follow when railroad traffic is in sympathy with national distress. Again, if we could formulate the law, assuming that there be such a law, which expresses the reliance, both as to production and demand, of the rarer useful metals on iron, and

their price, by comparison with the demand for and the price of iron and steel, we would convert the study of mineral statistics from being the driest and most tedious accumulation of isolated and often irrelevant figures into one of the most useful branches of economics. Moreover, whenever you discover a statistical fact or a statistical relation which tends to erect statistics into a science, you help to bridge that heretofore impassable gulf intervening between the exact sciences, which are independent of human volition, and therefore of human interference, such as mathematics and astronomy, and that still more important group of sciences in which man, as a sentient and willful being, seems to modify, if he does not control, the play of natural forces. But, as I said, I shall not worry you with columns of figures.

That we should be the largest producers of metals in the world is not to be wondered at, considering our preponderating size and advantageous geographic position among its industrial units, and taking into further account the fact that we are working virgin soil of an almost newly discovered continent, while our most important

competitors were metal producers from ten to twenty-five centuries ago. The surprising feature of our short industrial history is rather the amazing speed with which we have reached our dominant position.

And what, therefore, it is of utmost importance to us to study are the causes, including traits of national character, which have helped us towards taking the lead as metal producers; for, if we are to maintain it, you, as miners and metallurgists, must be inspired by the same spirit and follow the same general methods as have enabled the passing generation to raise this country from a position of dependence to that of a leader, not only in bulk of production, but in ingenious application of scientific principles to practical utility.

If we go back a little more than half a century to 1840, when the first industrial census was made, we find that there were scattered throughout the length and breadth of the land, from Maine to the wilderness of Wisconsin, 804 iron blast-furnaces, making 256,100 tons of pig iron, or one pig per diem per furnace, and 796 bloomeries and forges, making small quantities of wrought iron direct from the ores, or converting some of the

pig into malleable iron. These little furnaces and bloomeries and forges were not worked by trained metallurgists, but by farmers and backwoodsmen, who had to produce a local supply of iron, owing to the distance from a market and the difficulty of transportation, and who, wherever there was wood from which to make charcoal and water to give them blast, and a small or large deposit of rich iron ore, employed that mechanical ingenuity, self-reliance, and adaptiveness which have always been such marked characteristics of the American character to supply their wants. They were not in any sense educated metallurgists, but they possessed that same spirit which has converted into shrewd geologists, of a rough and ready type, and into skillful, practical, if not theoretical, metallurgists, hosts of men from every walk of life who have drifted from the East across the Missouri and become, as prospectors, the pioneers and real developers of our Great West. And had it not been for the infusion of this same temper into the builders of our magnificent modern metallurgical establishments, we would not be setting the pace to the world today. Had our Fritzes, Thomsons, Fricks, and

Carnegies been willing only to follow precedents and foreign tradition, and had they been hide-bound by the teaching of the schools, our output of iron and steel would not stand first on the list of the world's production. But even as the back-woodsman of the early decades of the last century turned from his plow and his axe to make iron in his own way, so our great ironmasters, not being hampered with overmuch reverence for the past, have fearlessly expanded their furnaces, applied new mechanical contrivances, enlisted electricity, and in many other ways applied the inventions, which they have been willing enough to accept from abroad, on expanded and often new lines.

Looking at the field of mining and metallurgy to-day, the prominent features of our progress have been, first of all, the large scale on which we work, and secondly, the very extensive use of machinery, which is a necessary concomitant to large production and extensive operation. The large scale on which our continent is built and the corresponding size of its natural resources have unquestionably stirred the imagination of the people and excited their energies. It is true that had we not possessed the natural resources,

we could not have made the progress, but there are other peoples who have possessed resources and allowed them to lie idle. Whence, therefore, our success? It is due in great part, though not altogether, to our substitution of machinery for hand-labor in every department of life. It has become a guiding and controlling principle with every American that it is more economical to use your wits than your hands, whether in the kitchen or the workshop; that nature's forces are less easily exhausted than your own; and that iron and steel can stand a heavier strain than human bone and sinew. Acting on this principle, whenever machinery can be made to do man's work, the instinct of the American is to devise some means of bringing this substitution about. When scarcity and the high cost of labor made labor-saving machinery a necessity, this trait of the national character found full scope for its exercise, and the necessity was abundantly satisfied. The material of which our buildings are erected is hoisted into place by machinery, and we are hoisted into our offices by machinery. We make watches by machinery for a few cents apiece, and locomotives for as few thousand dol-

lars. The ore for our furnaces is mined by machinery, transported to the mills by machinery, hoisted to the furnace-top by machinery, and dumped into the furnace by machinery. By machinery the liquid product is carried to the converter, blown by machinery into steel, and the steel, by a continuous mechanical operation, is wrought into manufactured shapes and loaded on the cars. Half a century ago, to make iron in the small furnaces then in blast, at least six days' labor was expended for a ton of pig iron alone. To-day, in some of our iron-mines, 4½ tons of ore is the tale of a man's daily work. In the large steel-works, the product of the blast-furnace department is 3½ tons of pig iron, and that of the whole manufacture is 2 tons of finished steel, made from the ore, per man employed, including the clerical force. In the field of copper, the impulse set by the ironmaster has reacted on the more sluggish copper metallurgist. Instead of the small brick cupola, in which, thirty years ago, it was thought a notable feat to melt 10 tons a day, furnaces are now running which consume from 400 to 500 tons of ore per day, and discharge their valuable contents into Bessemer con-

verters, which blow it into pure copper in as few minutes as it used to take days to roast and re-roast and fuse and re-fuse the ore when the cupola process of reduction was employed. And the reverberatory furnaces which were thought to do well if they smelted 10 tons a day have been so enlarged that, when gaseous fuel is used, as much as 150 tons per day can be passed through a single furnace. Mechanical dipping and ladling have also displaced the feebleness of men in bailing out the copper from the copper refinery by spoonfuls. Machinery has not so completely taken the place of the furnaceman in our copper-works as in our iron- and steel-mills; but every year witnesses a steady advance in that direction; and to-day ore mined in the morning can be loaded as copper into the cars by evening. A secondary but important effect of the extended use of machinery is the necessity which it forces on the manufacturer of producing large quantities. Take, for instance, the Bessemer converter as applied to copper. The smallest converter which can well be used economically will make from 1,000,000 to 1,500,000 pounds of copper per month from a 45 to 50 per cent matte. If,

therefore, this limit be reached, any increase of plant almost compels a doubling of the output—which would bring the production of such small works up to the total for the whole country in 1870.

The Yankee, after all, has been the creative genius of our continent, and we are all indebted to him for the infusion into the national life not only of his political ideas, but of his mechanical proclivities. The original Yankee was a mechanic and turned his talent to making wooden nutmegs and wooden clocks. He continues, as a mechanic, to make clocks, but it will probably be a German chemist who will make artificial nutmegs. The result of this Yankee infusion is that, as a people, we are more given to devising mechanical contrivances than to synthetical chemistry.

Among the mechanical factors which have helped to create our existing metallurgical industry, the railroad must be placed first. Through its agency, and aided by the steamer, ores can be brought to the fuel, or fuel to the ores, and through this concentration of crude material at favorable localities works of greater magnitude can be erected than the supply of crude material in any

single district could feed. The formation of our continent facilitates not only the construction and equipment of railroads on a large scale, which minimizes both original outlay and operating cost, but permits of the adoption of changes in obedience to the demands of progress, in a manner which it would be impossible to imitate in most foreign lands. A train can run from New York to San Francisco without once entering a tunnel or losing sight of daylight, and therefore structural changes to meet increased traffic can be made with less disturbance than in most other countries. Another advantage which we possess is that the railroads abroad were in a great measure built through, or to connect, large and populous cities and running through populous districts, when the art of railroad building was comparatively in its infancy. With us the great expansion of our railroad system has taken place when we had the world's experience to guide us. It has been no small gain to us that our active industrial life really commenced contemporaneously with the advent of the railroad; that it has been built upon the railroad as a substructure, instead of the railroad serving, as it has done abroad, as a mere

adjunct. Taking the railroad as a part of our great mining and metallurgical machine, and looking upon transportation as a mere branch of productive industry, it is interesting to follow say Lake Superior ore, from the mine back to the mine as steel rail, for by doing so we get a clearer conception of the all-important part machinery plays in the cycle of our mining and metallurgical operations. The railroad which connects the Minnesota iron mines with Lake Superior, and the huge trains in which their ore is hauled from Bessemer to Pittsburgh, are as much mining machinery as the steam-shovels by which the softer ores are handled, or the hoists by which the deeper ores are raised to the surface.

While scarcity and the high cost of labor in this country make labor-saving machinery a necessity of our industrial life, and while the necessity coincides with the tendency of the national character and the habits of the people, we must not flatter ourselves by supposing that we are the only people that use machinery, or that we were the first to make all these applications of it, still less that we have been great inventors of great

processes. We did not construct the first railroad; we did not build the first large blast-furnace; we were not the first to apply hot-blast to them. We did not invent the Bessemer converter with its beautiful dependence of chemical on mechanical forces. We did not invent the Siemens-Martin open-hearth process, nor suggest the basic lining, nor invent the dynamo. But we have applied Faraday's great discovery more widely than any of our neighbors. We now build blast-furnaces so much larger than theirs that one single Duquesne stack turns out annually as much as the 804 little furnaces did per diem or per annum in 1840, and we drive our furnaces at a greater speed—even though we shorten their lives. We get more blows out of our converters (as modified by Holly and others), and more work out of our rolling-mills as improved and remodelled by such men as John Fritz. We can do all this, not because we understand better than our rivals the laws of mechanics or of electricity, or have studied more accurately the chemistry of the blast-furnace, but because nature has supplied us with an abundance of material to work upon, and because we live up to the principle that

whatever our wits or our hands find to do we do with all our might.

The same is true in the metallurgy of other metals. The invention of all others which has helped in the development of our copper resources —the adoption of the pneumatic method in modified converters—was worked out abroad, not here; but for one ton of Bessemer copper made elsewhere we make 100 in this country. So likewise the electrolytic method of refining copper was proposed, used and substantially perfected in Europe, but works are considered there of large size which will turn out 10,000,000 pounds a year of refined copper, whereas we have more than one with a capacity of far over 100,000,000 pounds.

In all these instances our progress has been mainly due to the employment of mechanical and physical forces as auxiliaries to chemical and metallurgical processes to a greater extent than our rivals; and therefore I feel as if it were superfluous to even argue that a knowledge of mechanics and physics is as absolutely necessary to the miner and the metallurgist as an acquaintance with mineralogy or the principles of

chemistry and metallurgy. I use the word "physics" in its widest sense. Familiarity with the laws of heat is essential if we would use economically steam or hot air as motive powers. Electricity is doing our work under ground and above ground; striking our drills; cutting our coal; propelling our cars; pumping our water; hoisting our ore; moving our machinery in every department, generating heat for the decomposition of our more infusible chemical compounds as well as decomposing solid and liquid compounds in our many electrolytic operations; transmitting the power from localities where it can be cheaply generated to far distant localities where alone it can be economically used; lighting in mines, and works serving our ends and purposes in a hundred ways, but destined, as we learn more accurately and wisely how to use it, to be of still wider service in the future. But not only have we harnessed electricity to our mining and metallurgical machinery; we use air and water under pressure to an extent that makes it necessary that a mining engineer or a metallurgist, if thoroughly equipped, should be acquainted, not only with the laws, but likewise

with the application, of aerostatics and hyrdaulics.

Now, gentlemen, from what I have said you will gather that, as essentials to success as miners and metallurgists, you must possess not only a knowledge of what was formerly supposed to be all that was necessary, namely, of mathematics, chemistry, mineralogy, and geology, but you must be acquainted also with the fundamental principles and facts of mechanics and physics; for the educational equipment of a successful miner and metallurgist to-day is as much more intricate than it formerly was as the magnificent steam-engine, with which he will hoist his ore, is more complex than the windlass or the horse-whim, with which the primitive miner worked. As I have always said, without machinery—and machinery of the very highest type—we could not handle the quantities, without which our large organizations could not be supported. If we compare, for instance, the 125,000 tons of iron made in 1840 with the 17,000,000 tons made to-day, you have a standard by which you estimate the difference between the past and the present.

But while the applications of the principles of mechanics have alone enabled us to work on such a gigantic scale, the demand for quality has meanwhile become quite as exacting, and quality can be attained only by the application of chemical analysis to the elucidation of chemical laws. As professional men you will have to do, therefore, with the extremes of large masses and extremely minute quantities, the quality of the large mass being dependent upon the presence or absence, and the play of extremely minute quantities, of certain foreign bodies. To determine the existence of these and to explain their effects, you must be more or less familiar with chemistry and its allied branches. Thus if you are to handle ores and metals in bulk, you can do so only through a knowledge of mechanics; if you are to secure uniformity in quality, you can do so primarily only through the agency of chemistry. It is not so many years ago that even some of the largest metallurgical establishments in this country worked by rule of thumb, without the aid of a chemist, for when I came to Pennsylvania in 1875 no chemist was employed by what was then one of the largest

manufacturers of both pig iron and malleable iron in the East. But since the introduction of the Bessemer process, in which the making of good steel depends on the presence or absence of minute quantities of carbon, silicon, and phosphorus; and since the peculiar properties conferred on steel by minute quantities of nickel, magnesium, aluminum, and other metals are being taken advantage of, metallurgical works without a chemist, or a metallurgist without a knowledge of chemistry, has become an anachronism.

Horror at mastering such an appalling volume of knowledge, as would have to be acquired, if all the facts, phenomena, and theories of all these sciences had to be packed into the brain of a metallurgist and miner, might well deter any of us from undertaking the task of qualifying ourselves for creditably filling the humblest place in the ranks of the profession. The utmost that we can do is to familiarize ourselves with the main principles of the sciences I have referred to, so that when we come to occupy, as I hope most of you will do, prominent positions in one corner or another of the industrial world, you

will at least be able to map out the lines on which work is to be done, and be able to judge whether the technical specialists whom you employ are fit to do the work which you have assigned them.

It is true in our profession, as in medicine, that a specialist who is not more or less of a general practitioner is a dangerous man. At the same time the range of medical science has been so extended that the specialist has become a necessity. So in the walk of life which you intend pursuing, even if you decide to devote yourself and direct your studies to some special branch, you cannot escape the necessity, if you are to be useful men, of being generally informed on all of them. And if you take up no special branch, you will find yourself seriously handicapped, unless you know enough of every specialty to avoid being a mere slave of your special adviser.

In any case, what you want to study are the principles which underlie such sciences as come within the range of your studies, rather than the applications. The applications change—the principles never change. For instance, the type of furnace used to-day is likely to be discarded to-morrow. The Bessemer converter is being

rapidly displaced by the open-hearth furnace. The top furnace gases, which were only recently supposed to be turned to their most economical use in heating hot-blast stoves, are now freed from certain valuable by-products and used to drive large gas-engines. Hot blast, secured by the combustion of top furnace gases, and hot-blast stoves were hailed as the consummation of all economies. To-day frozen blast and the consequent condensation of oxygen is the aim of the iron-master. Thus in a thousand ways nature's forces and products are turned to newer and more economical uses. What you want to study are the forces themselves, and to be ever on the alert to make them do your special work.

And, as you will find, your real education will commence when you leave college and go out into the world and have a wider field of observation than you possess here. But if you are to derive the fullest advantage from this wider field, it must be by not omitting an opportunity of picking up stray pieces of knowledge, by observing the results of other people's experience. I used to have a professor of Greek who occasionally preached to us suggestive sermons from humble

topics, on texts which were generally suggested by the wisdom of the Greeks. I recollect his once breaking off his lecture to descant on the text:

> "Pussy cat, Pussy cat, where have you been?
> I've been to London to see the Queen.
> Pussy cat, Pussy cat, what saw you there?
> I saw a little Mouse under the Chair."

The moral hardly needs to be enforced. Our first duty as professional men, no matter where we are or what we go to see, is to have our eyes open, and our minds retentive of what to us must be the all-important objects of our professional life—gathering professional facts and professional experience. When Pussy cat at last got to Court, she forgot Royalty and its state and its circumstance, in attending to her particular function—watching the "little Mouse under the Chair." So in our case, no pleasure, no distraction, no self-gratification should ever stand in the way of entering a mine, visiting works, picking up a scrap here and a scrap there of professional information, and learning something from others' success as well as others' failure.

Wastes in Mining and Metallurgy

Address given before the Michigan College School of Mines, April 22, 1904.

I DO not unduly magnify our office as miners and metallurgists when I claim for ourselves, as winners of its mineral constituents from the earth's crust and producers of the useful metals from the raw products of the mines, a somewhat more dignified position than that of the mere merchant who disposes of our handiwork. But when we reduce our own and his energies to a common motive, we both stand on the same plane as money-makers.

It may be an inglorious position, but while we may, and should, personally work with higher aims than the sordid considerations of personal gain, as employees and representatives of capital we must make money, or the enterprises we manage will very soon become derelicts on the ocean of industry or ignorance. In trying to do so you

will come face to face with many problems and perplexities which may even assume the gravity of cases of conscience.

I do not speak of direct bribes, nor of the insidious bribes which are often offered under the guise of contingent fees; but of the feeling of guilt which oppresses a conscientious miner or metallurgist, when he is knowingly, and therefore willfully, wasting the treasures of nature, of which he should be the conservator.

The subject is a wide one and of many phases. For certain prominent shortcomings, such as the loss of heat, and therefore waste of coal, in generating power through the agency of steam and for the waste of power in its transmission, when once generated, we can hardly be held responsible, as the remedies for these fall within the province of the mechanical engineer. But there are, unfortunately, too many wastes for which we cannot shift the blame to the shoulders of others, and of some of these I wish to speak to you.

Theoretically, every valuable ingredient of an ore should be recovered. The day may, and will, come when this consummation of one of the higher ideals of metallurgy will be reached; but

to-day it is unattainable, partly because our methods are incomplete or defective, partly because economic considerations forbid us to recover by-products where there is no market for them. The latter excuse is, however, so rapidly disappearing under the extension of transportation facilities and the reduction of freight rates that ere long it will be our fault only if we are enlisted in the great army of wasters, instead of in the select company of the salvage corps.

In the recollection and experience of many of us, such notable advances have been made towards the consummation of what we all have at heart, that there is reason to hope the most sanguine expectations of the most enthusiastic believer in the salvation of nature's resources will be realized. Half a century ago every blast-furnace in the Black Country of England, and in our own then insignificant iron centers, was a torch, belching forth the flame, and the smoke and gas which are now used to heat the blast in the stoves, and to raise the steam for the blowing-engines, thus reducing the consumption of carbon in extracting pig iron from its ores to about one-quarter of what formerly was consumed.

It was later still before Mr. Bessemer succeeded practically in applying the heat generated by the combustion of the carbon and silicon in the pig iron to the conversion of cast iron into steel. It only remains to apply the waste heat from the converter to the generation of power for operating the blowing-engine to make this cycle complete.

Another example of the utilization of the fuel in an ore for the separation of its valuable constituents is afforded by the treatment of pyrite. Pyritic smelting can hardly be said to have passed beyond the stage of incipient development. Yesterday, hot blast was declared necessary. To-day, cold blast at high pressure is found more advantageous, but such progress is being made by many metallurgists, the world over, to place pyritic smelting on a sound technical footing, that before long we should see not only the sulphur in sulphuretted ores used to smelt the charge, but the sulphur escaping from the stack and the copper converter recovered as acid by the contact or some other process.

But a still more instructive example of the saving, not only of money, but of the valuable con-

stituents of pyrite has been worked out in Spain.

Till within a few years the minerals from the great lenses of pyrite at Rio Tinto and Tharsis were sorted and the portions richest in copper shipped to the chemical centers of the world. The poorer ore was roasted in heaps for the purpose of partially sulphatizing, and extracting as much of the copper by leaching as possible.

The pyrite exported is treated by the so-called Henderson process, which, however, should be more justly credited to Longmaid. After kiln roasting the crude ore, in order to extract most of the sulphur for acid making, the cinders are crushed and roasted with salt, whereby the copper is almost completely chloridized, and rendered soluble in the weak hydrochloric acid liquor obtained by passing the leach liquors through a condensing tower connected with the roasting-furnace. Iron is used as the precipitant of the copper, but before the cupriferous liquors pass to the copper precipitating-tanks the silver and some of the gold, which have been dissolved with the copper, are separated by iodide of zinc, as first proposed by Claudet. The tank residues,

practically free from sulphur and copper, consist of very pure iron oxide which was formerly used as fettling in the puddling-furnace, but now enters the blast-furnace. Thus the sulphur, the copper and the precious metals and the iron are all more or less perfectly recovered. And we have here, therefore, an instance of an attempt to save all the useful elements of the ore. But till the fuel used in roasting can be eliminated and till the salt consumed in chloridizing and the iron in precipitating are regenerated, or recovered in some valuable form, the series of operations, looked at from an economical point of view, is incomplete.

The treatment, however, of the second-class ores at the mine is what I wish particularly to call your attention to, as it conveys several lessons. The manufacturing chemists of Europe were driven to the use of pyrite about half a century ago by the unwise action of the Sicilian government in imposing a heavy export duty on brimstone. Three notable producers of pyrite soon entered the market—the Mason and Barry mines of Portugal, and the Tharsis and Rio Tinto,

on the same chain of deposits in the province of Huelva, Spain.

The Portuguese government forbade the roasting of pyrite by the Mason-Barry Co., which, therefore, was forced to screen and export all its lump ore. It was soon discovered that decomposition set up in the piles of raw fine screenings, when they were wetted, resulting in the extraction of the copper.

The fact, however, was overlooked as of any importance by the two great neighbors of the Portuguese company. They were building their second-class ore into huge heaps and roasting off the sulphur at enormous loss to themselves and the destruction of all surrounding vegetation. The Tharsis company was the first to correct its mistake, but though the Tharsis and Rio Tinto properties are only a few miles apart, it was years before the Rio Tinto was willing to abandon its old, obsolete and extravagant methods.

The result is now that both at Tharsis and Rio Tinto two or three million tons of raw pyrite a year are built into heaps and irrigated at intervals for four years, by which time the copper is practically extracted. The piles shrink in size by

about one-quarter of their weight, but when broken down for shipment to the chemical works of Europe and this country the remaining three-fourths consists of lumps of iron pyrite, retaining their original shape and structure, but of somewhat higher percentage of sulphur than before lixiviation.

I shall not discuss the interesting reactions that occur in the heaps during the four years of lixiviation, nor the still more interesting bearing of the whole process on the problem of the solution of metals in and from the earth's crusts, and their re-disposition as secondary ores. What I want to bring out is that there are saved to the world annually about 1,000,000 tons of sulphur, of which we get our share for the manufacture of the world's most indispensable chemical compound, sulphuric acid—sulphur which heretofore simply polluted the atmosphere.

At Rio Tinto there are in their two yards about 20,000,000 tons of badly roasted pyrite in heaps, collected during some thirty years, still slowly undergoing oxidation and yielding a little copper, but from which 7,000,000 tons of sulphur should have been recovered, whose value, at 10c. per

unit, would not have been less than $70,000,000 had the company's metallurgists been keenly alive to what was actually occurring elsewhere, even on their own Iberian peninsula.

There is no greater mistake than to work with too intense concentration and with your vision too firmly focused on your own enterprise. Technical travel displaces many an illusion and prejudice; and during your travels you will learn generally more than you would from books; for while few practical men will actually refuse to communicate their experience when asked, especially if you also reciprocate by communicating yours, still fewer are eager to take the trouble to publish their observations and their practice, even when their employers allow them.

Unfortunately there are a few employers who think that they can gain something by imposing secrecy on their officials. You will generally find they are willing enough to try and pump you dry; but they forget that the law of give and take is of universal force.

The waste of sulphur is not confined to Spain. The clouds which hang over Bergen Point and the northern part of Staten Island in the very

neighborhood of New York are a very visible and sensible protest against our own waste of that element.

A significant example of the recovery of all the valuable constituents of an ore is afforded by the present treatment of that complex mineral, franklinite, mixed with willemite-zincite, by the New Jersey Zinc Co. The minerals consist of iron, zinc, and manganese. Every attempt to extract the zinc by the Belgian method was futile, as the iron melted the retorts, but now that the Wetherell process of magnetic separation has been applied, a very pure zinc ore—the willemite-zincite—is recovered, zinc oxide is made from the franklinite, and the resulting iron and manganese are melted into spiegeleisen. As an iron ore the mixed mineral was of little or no value, because associated with so much zinc; as a zinc ore it was worthless because of its iron contents, and ten per cent of manganese added nothing to its attractiveness. Each of these metals was simply a deleterious waste product to the others. Now each adds value to its associate.

Such instances as these inspire the hope that

the self-interest of capital directed by the teaching of the members of our profession will soon remove from the technical industries the stigma of wittingly continuing to practice needless waste. But there remains much to be done even along lines already followed and methods already practiced. Take for example the waste of coal in mining it, and the appalling waste of by-products in coking it.

For many years after our limited stock of anthracite in Pennsylvania was first mined and marketed, the proportion saved was only 30 per cent of the vein mined. The balance was either left as pillars underground, which were never extracted, or thrown as waste into mountains of culm. Of late the figures have been nearly reversed, for about 60 per cent is recovered, and only 40 per cent is lost, a saving due to somewhat better mining, and to the burning of culm on perforated grates by forced draft. But this loss by no means represents the total, for in many localities, in extracting the coal from the best of the veins, coal in parallel veins is irretrievably lost, either in whole or in part by caving and crushing.

The demand for anthracite as a domestic fuel being urgent, and the supply being necessarily met from one limited region, arrest of production can hardly be permitted in order to study and apply improvements in methods of mining and preparation. This explanation may be accepted as a partial excuse for the waste of this rare and invaluable fuel. But no such justification exists for the waste of the by-products in the coking of bituminous coal; since the utilization of the waste gases was practiced long before the introduction of the Otto type of retort ovens, which is merely an amplification of the illuminating-gas plant.

There is made in this country about 22,000,000 tons of coke, of which less than 2,000,000 tons are made in by-product ovens. The actual proportion is 5.4 per cent of the whole, while 94.6 per cent is made in non-by-product ovens. The coke is made from 34,000,000 tons of coal, from which about 1,800,000 tons alone yield by-products.

Average coal in its coking yields per ton as by-product about 20 lbs. of ammonium sulphate, when the ammonia is recovered as sulphate, and

10 gals. of tar. If these by-products were recovered from all the coal coked, there would be saved about 340,000,000 gals. of tar, worth at $5 per ton $8,168,000, and ammonia sufficient to make 340,000 tons of ammonium sulphate, worth at $60 per ton $20,400,000; and allowing 60 per cent of the gas to be consumed in heating of the ovens, there would be available for power 140,000,000,000 feet of gas, each cubic foot of which, if burnt, would yield about 500 B.T.U. of heat.

The total volume of gas now wasted, therefore, after thus deducting 60 per cent, would give us 72,000,000,000,000 B.T.U., and allowing 12,000 B.T.U. per horse-power hour, 6,000,000,000 horse-power hours, if burnt in gas engines—or far more than the power now actually produced from the Falls of Niagara. The figures of loss are startling and appalling. The tar wasted would enable us to outstrip Germany's famous lead in the manufacture of aniline dyes and other hydrocarbon products, if we brought Germany's perseverance and skill and chemical science to bear upon the industry. The gas would yield ammonia enough to require the multiplication of our acid and fer-

tilizing works for making cheap manures with which to revive our depleted prairie lands, and power enough, if distributed, to create new centers of manufacturing activity.

If Germany can afford the expense of coking ovens of the retort type, with the object of making so good a coke out of her inferior coals that they can compete with our own in the markets of Mexico, surely we can do the same. And we would do so, were it not for the reckless haste to make money, and make it at once with whatever appliances we possess.

None are so willing as our own manufacturers to discard an old plant and replace it at any cost with new, but they hate complications; and therefore it will take time to persuade our coke manufacturers to complicate the simple process of coke making in the bee-hive oven—as long as it makes a good coke out of our splendid coals—with all kinds of chemical processes, which must be operated by chemical experts who are even more obnoxious than their processes.

But the gains are so obvious that prejudice must rapidly vanish, and we shall soon see two great changes taking place. More coke will be

made at the works where it is consumed, for coal can be transported more cheaply than coke, on account of its lesser bulk, and it does not suffer in transportation, if intended for coking; whereas, coke loses in volume and efficiency by attrition in carriage.

If, moreover, the 25 to 30 per cent of volatile gases given off, even from the bee-hive ovens, are burnt, as they issue from the oven, under steam boilers, or, better still, exploded, after purification, in gas engines, the total weight of combustibles carried from the mine will be burnt either as coke in the blast-furnace or as gas for the generation of power.

There may be furnace plants in localities where the by-products of the coke oven are valueless, though they are becoming fewer with the extension of our railroad system. But even so, it will generally be found cheaper to coke the coal at the furnaces where it is to be consumed, and then utilize the escaping gases for power purposes, than to haul, on the same trains from the distant coal-fields, coal for generating power and the costly bulky coke already wastefully deprived of its volatile gases.

The utilization of the gas at the great centers of the coke industry, as in the Connellsville district, for the generation of power, would formerly have been impossible; but now that long distance electrical transmission under high voltage has been practically effected, there is no excuse for wasting the energy which escapes with the gas from 25,000,000 tons of coal coked in Pennsylvania alone, where power is in such demand.*

When Siemens introduced his gas producer he imagined the time would come when gas instead of solid fuel would be sent from the mine to the consumer. The conception has never materialized, for obvious reasons. But none of the objections which prevail against the transportation of gas hold good against the transmission of the more subtle mysterious agent—electricity. And therefore, with the interposition of only one—or for certain purposes, two—conversions and trans-

* Erskine Ramsay, in a paper on the "Generation of Steam from the Waste Gases of Coke Ovens," communicated to the Alabama Industrial and Scientific Society, Vol. III, 1893, calculates, from his experience at the Pratt Mine coke ovens in Alabama, that if the 18,000 Connellsville ovens were run to their capacity of 50,000 tons of coal daily, the escaping gases would be equivalent to 18,000 tons of coal burnt under steam boilers.

formations, we shall sooner or later see Siemens' dream realized; when the gas generated at the mine will be transmitted as electric energy to the consumer, and the smoke nuisance, the ash nuisance, and a host of other nuisances, if they do not disappear from our cities and our homes will be notably reduced.

The effect of the saving of waste on the price of our staple metals will be incalculable. In fact, when all the volatile products of the coke oven and of the blast-furnace, which are now saved in Scotland, are deprived of their heat-giving properties, and their chemical constituents, and when the slag as well as the metal have returned their heat to man instead of to the atmosphere, and the slag itself has been turned into cement, or some other useful article, it will be a question as to whether the pig iron is the principal object of manufacture, or one of the by-products.

There is another waste for which we are responsible, but for the removal of which I cannot see so speedy an outlook; I mean the burying of our forests in our mines. I do not know how many feet of lumber, board measure, are actually and irrevocably covered up in your copper and iron

mines, though I know how intelligently and earnestly your iron masters have worked to stop this heinous waste by replacing timber with steel and concrete, but I am ashamed to say that twenty-five feet of Oregon pine replace every ton of copper ore we extract from the Copper Queen. There the quantity used is exceptionally large, for the ore is in great measure extracted from soft, irregular masses embedded in a wet clay matrix, and square setting, as a measure of safety, has to precede the ore extraction. We cannot see how to actually displace this expensive and wasteful method by back filling or caving, and yet it seems iniquitous to waste so valuable and vanishing a natural product as timber in recovering another of perhaps less national importance.

The preservation of our forests and their perpetuation, by replanting, are of course a subject which you in Michigan must have very near at heart, and therefore to Sweden you should look for lessons in the economical use of your forest resources. There is still in operation a public company—the Kopparberg—whose charter dates back to the thirteenth century, and which depends still for its prosperity on the lumber cut

from the tracts of forests which then came into its possession. Nothing is rejected. What is not used for pulp making and dimension lumber is devoted to metallurgical purposes—converted either into charcoal for the blast-furnace or into gas for steel making in the open hearth furnace. Not a twig nor a grain of sawdust goes to waste; and the price Sweden obtains for her steel is her reward for and warrants the care and the cost involved. It also goes without saying that a tree is planted to replace the tree cut down. But in Sweden men and their children are willing to wait till a tree grows. Here we are not. And there the State, conscious of its immortality and provident of the national resources for future generations, puts some checks on the selfishness of the individual who looks only to to-day. This phase of the subject involving the duty of the State to interfere with the free action of the individual and with the reckless waste of the nation's resources is, I know, a delicate one, yet none the less momentous. But to discuss it would lead us far afield of our present object, which is to consider cursorily our individual obli-

gation to use our best endeavors towards minimizing the evil.

My own experience has been largely gained in working mines and treating the copper ores of the West, and dates back to the period when both Arizona and the Butte copper interests were in their infancy. I have therefore observed the heavy costs involved through losses which are incidental to inexperience, and which must necessarily occur during the premature development of mines on a large scale. I can therefore also appreciate the impossibility of avoiding them altogether. The few remarkable instances, out of many, which I have quoted, of waste on a national scale, it may not be within the power of many or of any of us to remedy, but we shall all have to consider again and again what provision can be made to preserve, for future treatment, valuable material which at the moment is virtually waste.

It is difficult to forecast the future and to anticipate the economical charges which time will bring with it; but of this we may be certain, that the drift of events will be inevitably toward lower treatment charges and therefore the utilization

not only of lower-grade ores, but of what is to-day actually rejected as waste. In mining, therefore, it is better to store at surface, if the character of the ore will permit of it, lower-grade ores than to bury them in the stopes as filling, under the certainty that the day is not distant when they will be valuable; or if they must be left underground, separate the ore, no matter how low, from actual waste. It may cost a trifle more at first to do so, but in the end it will pay, and the end must always be kept in view. I have to do with a mine which, when first worked, was 125 miles from a railroad, and the standard of the ore fed to the furnace was fixed by the management at 18 per cent of copper. With lower freight and cheaper fuel the standard was reduced to 12 per cent. Now we are satisfied to feed our furnaces with ore of between 6 and 7 per cent. During the first stage 12 per cent was waste; during the second 7 per cent was waste. To-day it would be rash to count any copper-bearing material as actual waste; but at each stage of development the ore rejected for the moment was treated as worthless and thrown away as stope filling, and is recovered, though at needless cost. As, how-

ever, the property has thrice changed hands since the early days, the original owners would have derided the suggestion that, for the good of their successors, they should have incurred a dollar of unnecessary expense. In very truth, however, the property would not so often have changed hands had the future and not the immediate present been more prominent in the calculations of each successive administration.

The ores of the Arizona mines have changed and so have the methods of treatment. For years it was considered that with the appearance of sulphur would date the rapid decline of the mines. Then that valuable element was regarded as pernicious and worse than waste. To-day it is in urgent demand; for with the introduction of the pneumatic method, and the cleaner slags made by matte smelting, it is found cheaper to make copper from a sulphide mixture, though by several operations, than from carbonate ores by a single furnace treatment. Moreover, we are everywhere resmelting the rich slags formerly made, where they were preserved. Unfortunately, at certain furnaces they were considered as of such little prospective value as to have been

granulated and run into the river or so dumped that they have been washed away. We are not to blame for having made copper direct from carbonate ores, though it involved waste, for sulphuretted ores were not obtainable nor would it have paid to reduce a sulphide charge by the older methods in vogue twenty years ago. But we were at times to blame for not anticipating, and believing that metallurgy and railroading and all associated industries would rapidly advance, and put cheaper methods, cheaper fuel, cheaper transportation within our reach, and thus ennoble what was then waste into valuable material.

The same has been eminently true of the waste from gold, silver and copper concentrating-mills. Only some 60 per cent of the hundreds of millions which the Comstock lode yielded was recovered at the time, and yet at first those enormously rich tailings were not even collected—such was the haste of the miner to empty that stupendous deposit, which should have made Nevada prosperous for generations instead of whirling the whole country into a mad dance of reckless speculation. And at Anaconda there

are said to be tailings by the millions of tons which will run from 2 to 2½ per cent of copper, made when a large production rather than minute economies was the order of the day. The values locked up in our Arizona slags, in the Comstock slimes, in the Anaconda tailings, all represent a large waste and heavy loss, even though they may be in part recovered by subsequent treatment.

Who or what is responsible? Primarily the company system and the heavy capitalization of our large mines, involving a large output at any expense, if the value of the shares is to be raised or their price maintained at the financial centers.

Overcapitalization generally demands overproduction, and overproduction almost inevitably involves waste at some stage of the metal's progress from the mine to the consumer.

The company system and the company managers may be greater sinners than ourselves, for they set the pace, and we must maintain it. At the same time the management at the eastern end is generally composed of able and honest business men, whose ignorance of technical details obliges them to rely upon their technical

advisers, and the more worthy the members of the technical staff are, the more implicit will be the confidence imposed in them, and, therefore, their influence. On us, therefore, ultimately rests the responsibility in great measure of correcting the evils of waste to which I have drawn your attention. For, depend upon it, if from no higher motive, you will find the eastern management willing enough to spend money in order to save money, and there is always money saved in avoiding waste. But apart from this sordid view of the subject, it will elevate your whole conception of the dignity of your profession and your work, if you regard yourselves, which indeed you should be, as the preservers of the gifts with which a beneficent Providence has stored our world, for next to being a creator, the highest function a man can attain to is being a saver—a savior.

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